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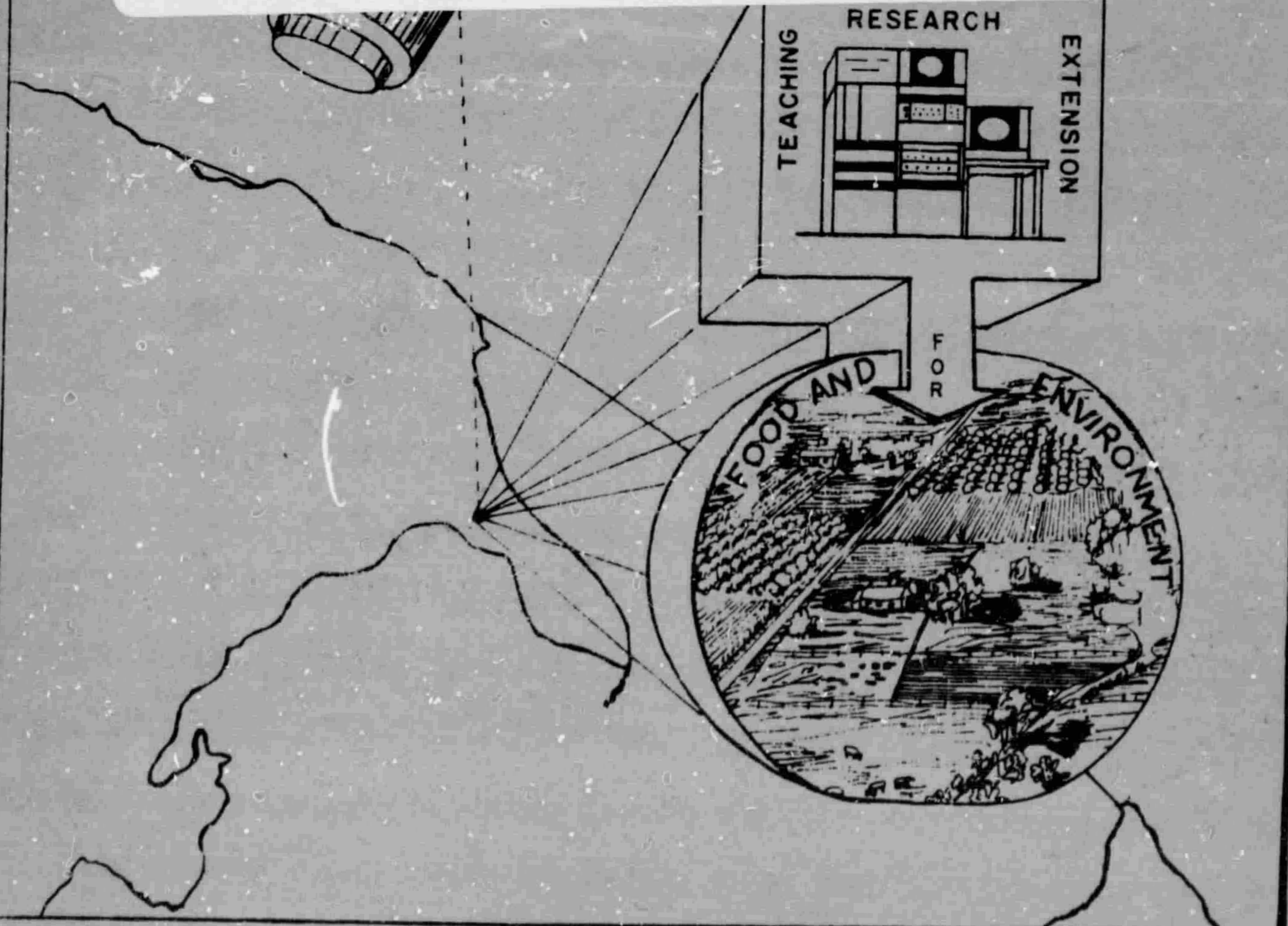

In Cooperation With:

National Aeronautics and Space Administration
South Florida Water Management District

FLORIDA WATER RESOURCES - NAS10-9348

Executive Summary

April 1980

This Executive Summary includes a condensation of the purpose and results of the major technical tasks and the Long-Range Planning task of the Florida Water Resources Project. The detailed technical information is described in the Florida Water Resources Final Report, April, 1980.

The State of Florida has a very different set of hydrological cycle systems which make it unique among the southeastern states. These unique water supply and storage factors within this system contribute to problems within the State concerning the availability of water to meet the expanding competitive needs of the State's urban, industrial, and agricultural communities.

There is a direct conflict created within the State on the demand of water by the various users. In the past the large agricultural demand has not created any problem; however, with the rapid population increases in the State and the new industrial expansion, the user conflict grows daily. This growing conflict between users, coupled with the unique Florida hydrological supply problem, creates a delicate balance between supply and demand which requires specific extensive data bases and models to help water resources managers make realistic decisions concerning their water resources.

The University of Florida, Institute of Food and Agricultural Sciences (IFAS) had previously worked with several of the Florida Water Management Districts, and therefore was familiar with many of their problems. IFAS had also been working with the National Aeronautics and Space Administration (NASA) Kennedy Space Center Applications Projects Branch (KSC) on remote sensing research projects directed toward applying NASA technology to agricultural problems. With this background IFAS and KSC recognized that many developments in space technology had potential for application to the critical problem of Florida's water resources. Since the South Florida Water Management District (SFWMD) had been in operation for many years and had worked with IFAS on water management data needs in the past, it was decided to develop a joint Water Resources project among IFAS, NASA, and SFWMD. This resulted in the submission of a NASA funded Florida Water Resources Management, Research and Technology Objectives and Plans (RTOP) (UPN 177-55-91) in June of 1977. This project proposal not only included a beginning effort of the development of remote sensing

data techniques for the SFWMD, of more significance it required the development of a Long Range Plan. This Long Range Plan would include the cooperation of all five Florida Water Management Districts and culminate in the development of a statewide Water Resources Management Information System, based on state-of-the-art remote sensing and Automatic Data Processing (ADP) technology. This system would provide an adequate data base to help all of the Water Management Districts solve their critical water supply and water use allocation problems. The project was proposed as a five-year research program, however due to NASA funding problems, only one year of the research program was funded. Therefore, the results of the research program can only be considered interim and further research would be required to develop final conclusions.

This one-year research project consisted of seven technical tasks and the development of a Long Range Plan required to implement the entire five-year research program. This Executive Summary includes a condensation of the purpose and results of these technical tasks and the Long Range Planning task.

A method was developed whereby the water balance budget model results for Lake Okeechobee could be improved by using LANDSAT data to map the complex littoral zone vegetation by combining these plant community data with their respective transpiration rates. Since the plant species are linked to elevation through the hydroperiod, a vegetation classification can also provide an approximate map of ground elevations. In order to classify the vegetation of the littoral zone, digital data from the LANDSAT earth-orbiting satellite was analyzed on General Electric's multispectral image analyzer, the Image 100. A typical LANDSAT Image 100 classified littoral zone vegetation map is shown in Figure 1. Eight major marsh vegetation communities including spikerush, water-lily, cattail, cordgrass and sawgrass, beakrush, willow, grasses, and guava, are depicted in Figure 1. The area occupied by each vegetation community and for each stage elevation range were used in the Lake Okeechobee water balance

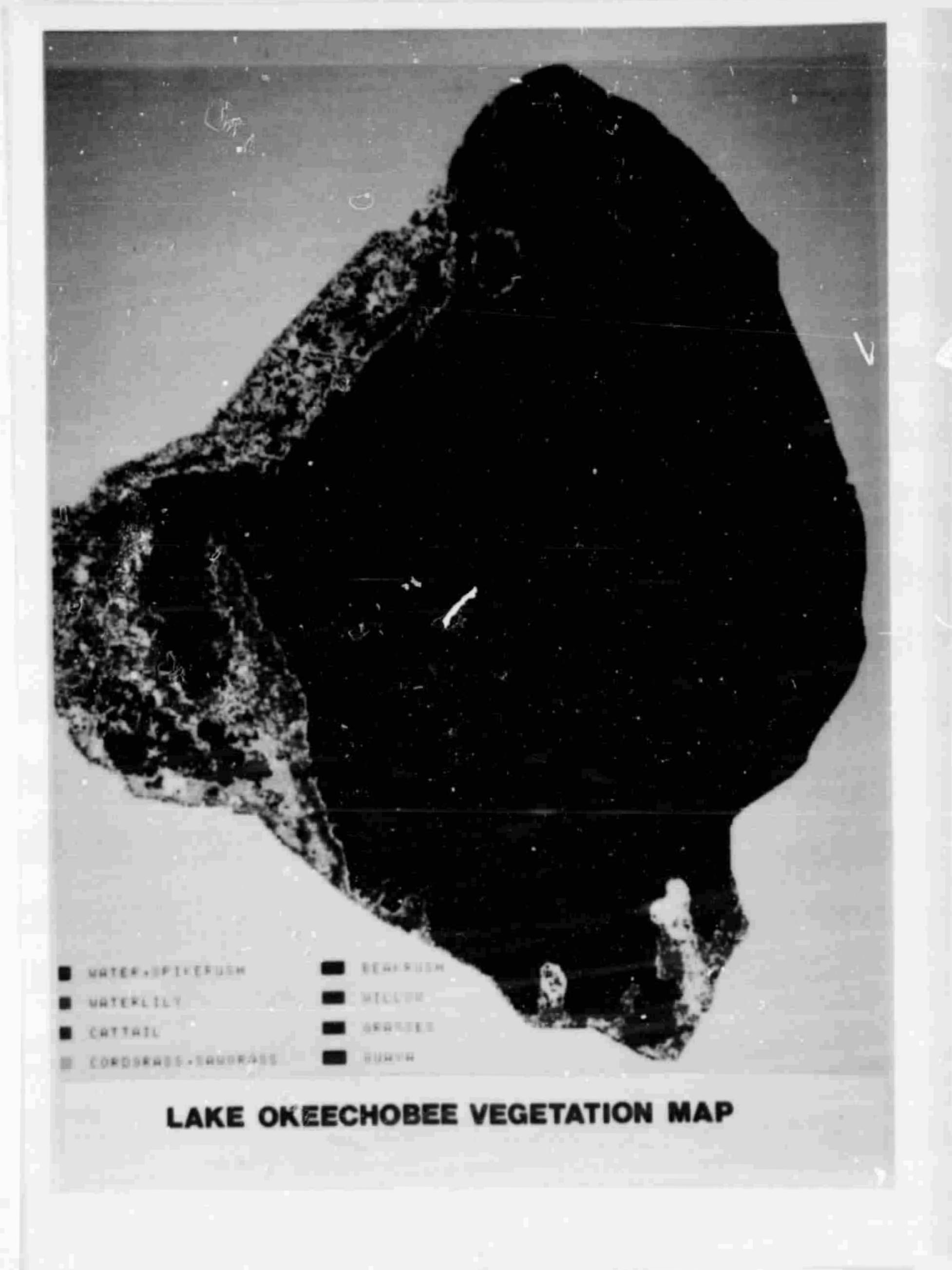

Figure 1 LANDSAT Classification Map of Littoral Zone Vegetation.

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budget model to develop improved estimates of lake volume. These estimates were then compared to estimates made by conventional methods. The model results based on this LANDSAT information demonstrated a 94 percent reduction in cumulative lake stage error and a 70 percent reduction in the maximum deviation of the lake stage. To verify their general applicability, these techniques should be tested in other lake and marshland communities.

In south Florida (SFWMD), three large tracts of grassy marshland have been set aside to act as natural water conservation areas. The volume of water stored in these conservation areas are questionable because these areas are large, remote, flat, and heavily vegetated. LANDSAT Band 5 and Band 7 radiance values were statistically correlated to eight known water depth (stage) values. From this correlation a complete water depth map of Conservation Area 3 was made by extrapolating the correlated values to radiance values throughout the area. A map of this water depth/radiance correlation for Conservation Area 3 (upper and lower) is shown in Figures 2 and 3. Correlation coefficients as high as 0.75 were obtained from the October 17, 1976 LANDSAT scene. The water surface area occupied by each water depth was used to compute the storage capacity in Conservation Area 3a. The volume of the storage area was calculated for various stages and compared to conventional data. The results of this comparison showed errors from 0 to 30 percent with the largest error existing between 7.17 and 8.17 ft MSL. Further research is needed to refine this technique for all stage levels and to test it in other conservation areas.

The mapping of the vast Florida wetland areas is a difficult task due to the difficulty of obtaining access to the areas. Also very little research has been done on the flow resistance characteristics of these natural vegetation communities, therefore one value of Manning's N roughness coefficient has frequently been used. A task was undertaken wherein LANDSAT data were used to

Figure 2 Upper Section of Conservation Area 3a Water Depth Map (LANDSAT Bands 5 and 7).

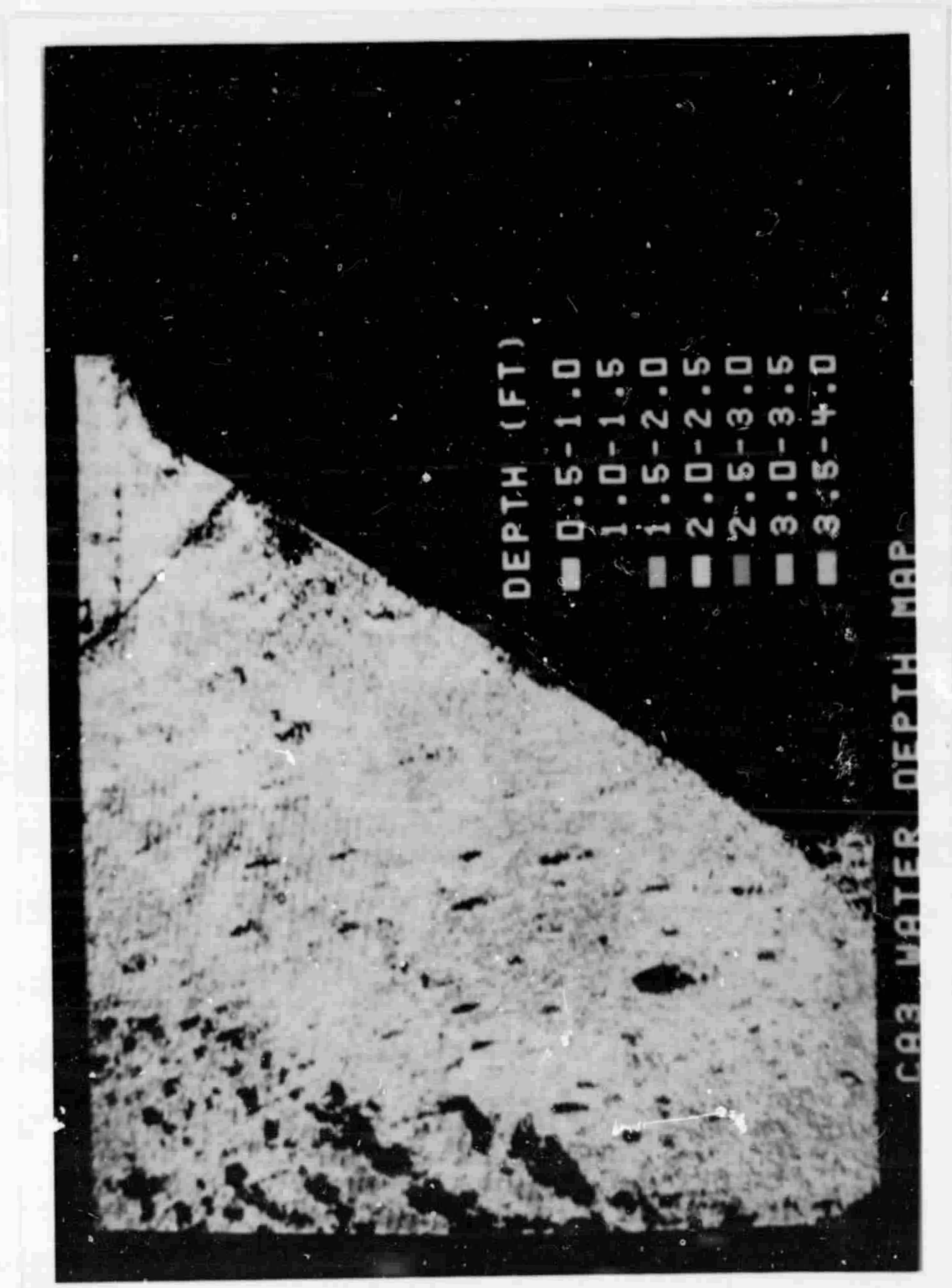

Figure 3 Lower Section of Conservation Area 3a Water Depth Map (LANDSAT Bands 5 and 7).

classify a typical marshland drainage basin, Chandler Slough in the Kissimmee River Basin. A preliminary Image 100 vegetation classification was performed on cloud-free spring and fall scenes from various years. the LANDSAT scene recorded on April 11, 1976, was found to give the best vegetation definition. The vegetation discrimination was found to be most closely linked to radiance in Bands 5 and 6. Five vegetation categories consisting of dense cypress; trees and woody shrubs; buttonbush, wet prairie and willow; wet prairie and broadleaf marsh; and low grass and pasture were classified for the Chandler Slough area as shown in Figure 4. Detail flow measurements were made at various water depths throughout a yearly vegetation growth cycle at some twenty-one test sites throughout the area, representing various sub-sections of the above classes. From these flow measurements a family of Manning's N flow curves were developed for each complex vegetation test site for various water depths at various water depths at various growth seasons. Maximum flow resistance values ranged about 5-6 fold the minimum values over a flow depth of 40-60 cm. Flow resistance values below the water surface increased and formed a maximum at the peak in the vegetative growth and then decreased with decline in vegetation growth. The flow resistance values showed consistent curvilinear relationships with vegetation density. These Manning's N curves are being used by the SFWMD to develop better information to deal with water resources problems in marshland vegetated flow areas, such as flood routing, backwater curve computation, channel improvement and scour problems, etc.

The concept of lake volume measurement from satellite surface temperature data is to predict lake volume from the energy balance of the lake. The differential time-rate of change in internal energy of a column in the body of water would be equal to the sum of the exchanges of all energy flux density components. A test of this theory was completed using a typical shallow Florida lake, East Lake Tohopekaliga near St. Cloud. On April 11 and 12, 1978 aircraft

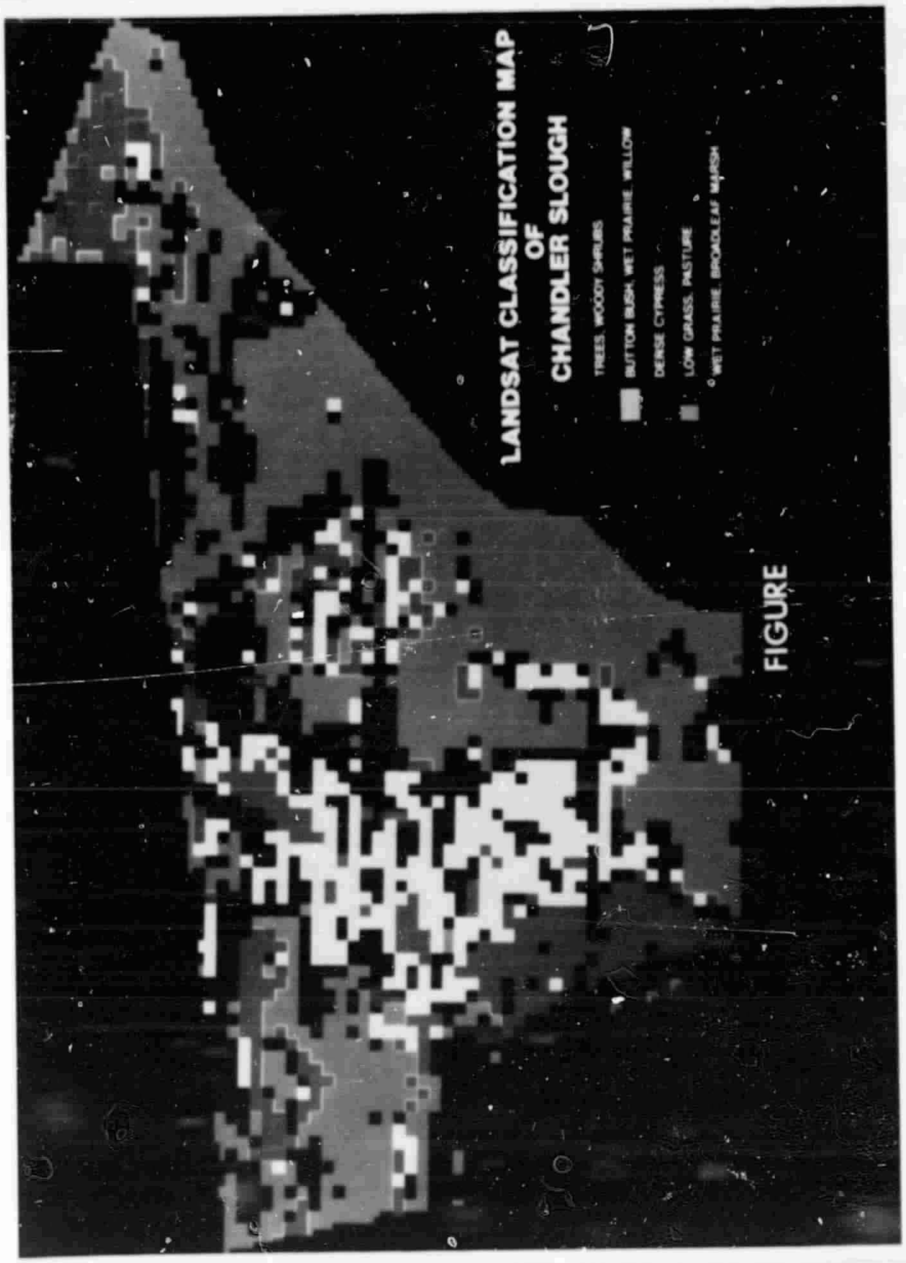

Figure 4 LANDSAT Classification Map of Chandler Slough.

thermal scanner data over a 24-hour period was gathered for the lake along with considerable surface and subsurface data using an instrumented boat. Sounding information used to calculate the actual lake volume was gathered by the SFWMD. Calculations from these data did not adequately predict the average lake depth due to thermal stratification of the lake. Therefore, a stratified lake model (a FORTRAN program called LKVOL) was developed to predict lake depth and volume from measurement of internal energy change and energy flux exchanges. These calculated lake areas and volumes when compared to actual values, were at best only within 10% of each other. It does not appear that the procedure as now developed would consistently provide sufficiently accurate results for operational use. More actual test data need to be gathered to further refine and develop the lake volume model.

Present methods of obtaining rainfall amounts over large areas are unsatisfactory because rain gauges are placed far apart and their point records do not reflect true amounts received on the whole ground surface. A method developed by Scofield and Oliver (1977), based on the empirical relationship that in convection cumulus clouds there appears to be a correlation between the cloud top brightness temperatures and the temperature gradient to the amount of rainfall. Software was developed to use half-hourly Geostationary Operational Environmental Satellite (GOES) imageries to measure these temperature relationships by the Scofield and Oliver methods and check the developed rainfall data against ground based radar data (from the University of Miami) and rain gauges. However, due to the lack of coordinated GOES and radar data, adequate correlation was not obtained. Other similar research by Griffith (1978) and Follanshee (1973) does indicate that such methods could provide very useful rainfall data for the Florida Water Management Districts. Further testing of these methods within the Florida climatological regime needs to be accomplished to make such a system operational.

A typical Florida drainage basin, Taylor Creek in south Florida, was chosen to test methods of developing evapotranspiration (ET) values for various vegetation types and climatological conditions using aerial thermal scanner radiation data and ground measured climatological data. Two dissimilar areas were chosen for study of plant cover. One area was primarily improved grass pastures and the other area was a citrus grove. Figures 5 and 6 are thermal images from an aircraft-mounted thermal scanner (8-14 μm) flown at heights of 1.36 km and 2.43 km, respectively. The thermal data of Figure 5 for pasture were obtained at 1222-1225 EST on April 28, 1978. The thermal data of Figure 6 for citrus were obtained at 1432-1435 EST on April 26, 1978. These two thermal pattern scenes were analyzed for the percentage of land area in seven 6^{o}F temperature intervals. The percentages of the scenes were used to compute ET from each component. Also, the citrus grove scene was further divided into tall and short vegetations. In areas of vegetation, the physical condition of a given species seemed to be differentiated in the thermal imagery. In Figure 6, thermal imagery of complex vegetative canopies associated with citrus and rangeland is shown. Three methods were investigated for calculating ET on a regional basis. All computed sensible heat flux density first, and then computed ET from the energy balance equation. The first was to compute a bulk aerial resistance (r_B) from the ground truth sensible heat flux measurement, and from remote sensed surface temperature, and from air temperature. The second method was to develop atmospheric stability-corrected heat transport coefficients to apply in the turbulent boundary layer above the grass surfaces. It was found that the temperature difference in the turbulent layer (ΔT_t) could be accurately calculated from the surface temperature to air temperature difference (ΔT_T). This ΔT_t was then used in calculating ET by first calculating the sensible heat flux (H). The third method used integrated profile stability corrections. Accurate predictions from this method require the ability to determine the

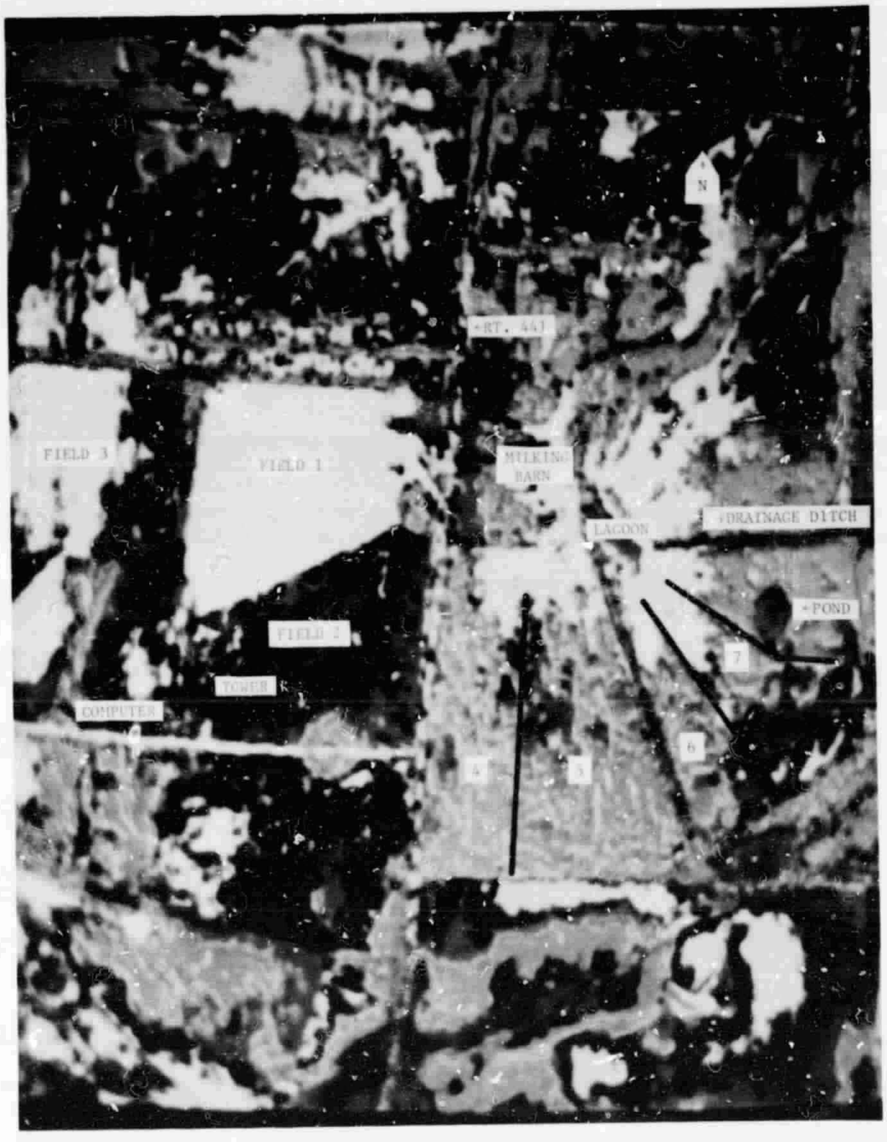

Figure 5 Infrared Image of Pasture Scene in Taylor Creek Watershed, April 28, 1978, at 1222-1225 EST. Photographed from Image 100.

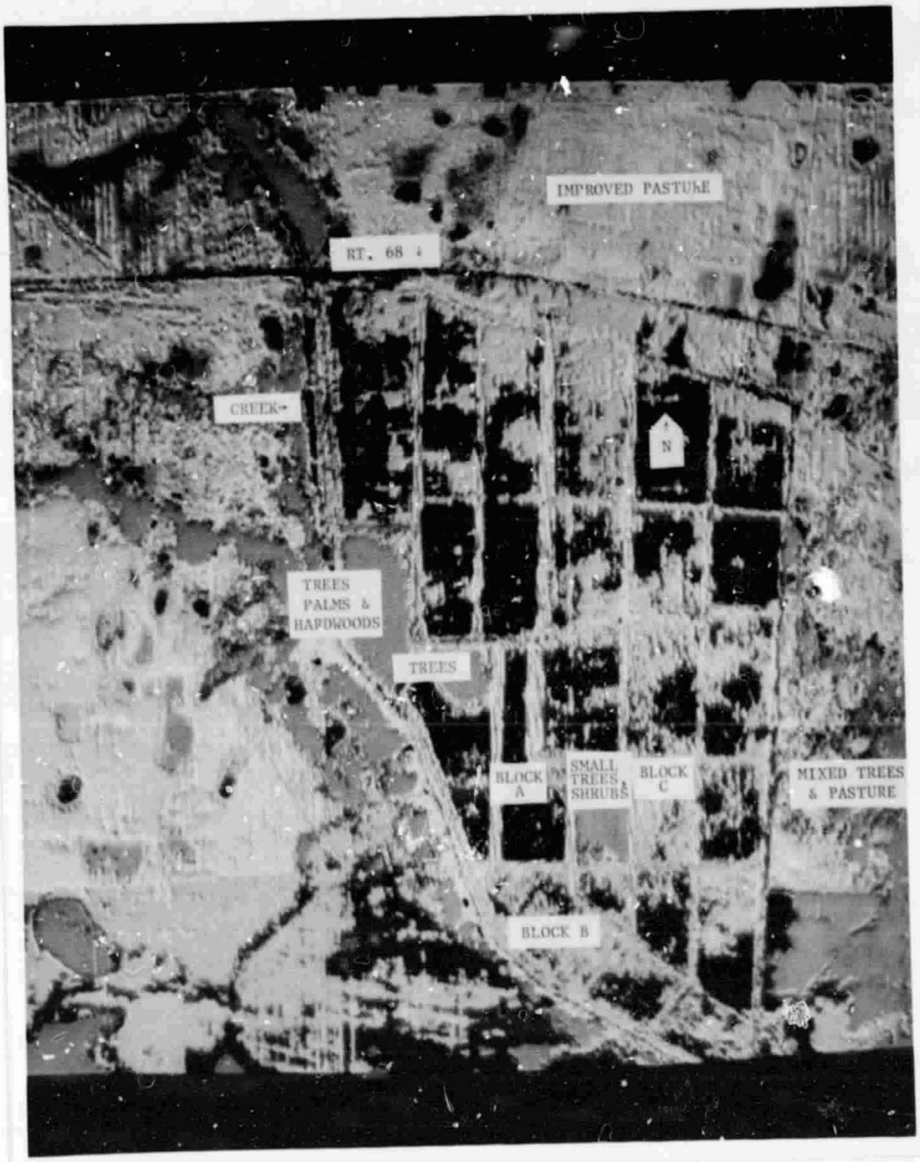

Figure 6 Infrared Image of Citrus Grove Scene in Taylor Creek Watershed, April 26, 1978, at 1432-1435 EST. Photographed from Image 100.

effective height of the heat source (Z_H) to apply to the effective source temperature. Once this value was determined, the regional ET calculations were made for the pasture scene. The methodology was tested only over short grass surfaces. The techniques tested in the research proved to be more realistic in predicting ET for short grass areas than the use of the common pan evaporation technique. Future work is needed on other types of vegetated surfaces to better define effects of wind speed, stability, surface roughness, plant height, leaf area index, and soil moisture conditions on aerial resistances. Comparisons should also be made between ET computed by relatively detailed surface temperature measurements and relatively large-scale pixel temperature measurements.

An evaluation was made of the SFWMD three-dimensional aquifer model to determine the feasibility of using remote sensing techniques to supply a data base for the model. It was found that remote sensing is most applicable to the model in defining parameters which follow the movement of water on the surface, in describing the areal extent of surface conditions (e.g., geology, drainage, vegetation) which might affect both surface flow and flow between surface and groundwater, and in locating direct evidence of links between groundwater and surface water (e.g., free-flowing wells, areas of good drainage). Radar sensors currently under development may soon extend this range below the surface. Further development of this model by the SFWMD should be guided to allow the better use of remote sensing as a data base.

The final goal of the project was to develop a complete Water Resources Management Information System based on the latest state-of-the-art remote sensing and data processing technology and to demonstrate and then implement this system on the various Water Management Districts' computer hardware. To develop a Long-Range Plan for accomplishing this goal, a joint NASA, IFAS, and WMD study team was chartered. Major planning meetings were held with four of the five Water Management Districts from the beginning of the project in

March 1978 through June 1978, when the FY '80 research proposal was due into NASA Headquarters. From these meetings twelve detailed research tasks were defined. Five major areas of concern that tended to be common to all Water Management Districts were uncovered. These were: Hydrology, Water Use, Environmental, Climatology, and Data Base Management. These major areas of concern were the areas wherein the Long-Range Plan would concentrate in developing means for meeting all of the common needs of the Water Management Districts which would culminate in a complete Water Resources Management Information System. In August of 1978 notice was received from NASA Headquarters that the five-year research and development program, proposed in June 1978, could not be funded due to limited NASA funds. Therefore further development of the Long-Range Plan ended and effort was concentrated on documenting the results of the first year's study.